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ABSTRACT

The purpose of this module is to teach the basic metric measures of length, area, volume, capacity, mass, and temperature. It introduces students to metric prefixes, abbreviations, and unit conversions with the system. Illustrative and optional material compares metric measures to our familiar American standard measures. The purposes are accomplished through the use of detailed explanations, experiments, charts, games, and manipulatives. After an introduction which points up the need for a uniform international measurement system, the student proceeds through a series of experiments and worksheets. Most problems are related in some way to a physical model or actual measurement device. (Author/MK)

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INTRODUCTION TO METRIC MEASUREMENT

by

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Overview

The purpose of this module is to teach the basic metric measures of length, area, volume, capacity, mass and temperature. It introduces students to metric prefixes, abbreviations and unit conversions with the system. Illustrative and optional material compares metric measures to our familiar American standard measures. The purposes are accomplished through the use of detailed explanations, experiments, charts, games and manipulatives.

After an introduction which points up the need for a uniform international measurement system, the student proceeds through a series of experiments and worksheets in which he learns to use the basic metric units of length, area, volume, capacity and temperature. As he works with these units, he recognizes the advantages of the decimal structure of the metric system. Most problems are related in some way to a physical model or actual measurement device.

Objectives

.Students will be able to use the basic metric prefixes and understand their meaning and relationship.

.Students will be able to interpret and use common metric abbreviations.

.Students will be able to use the basic metric measures of length, area, volume, capacity, mass and temperature.

.Students will be able to estimate measures of length, area, volume, and mass in metric units.

.Students will be able to convert from one metric unit to another by using the properties of the base ten system; e.g., 12 mm = 1.2 cm.

.Students will be able to read the metric temperature scale.

.Students will know the basic unit of metric land measurement (hectare).

Activity Description

Act. #1. Introduction - Need for and history of the metric system.

Act. #2. Thomas Jefferson, a Pendulum, and the Meter - Show ways determining the basic unit of metric system - the meter.

Act. #3. Using a meter stick and learning metric prefixes - puzzle or concentration game.

Act. #4. Practice in metric measurements - projects and puzzles.

Act. #5. Area measurements

Act. #6. Volume measurements

Act. #7. Mass (weight) measurements

Act. #8. Land-area (optional)

Act. #9. Media temperature measurement

Act. #10. Review crossword

Act. #11. Conversions - English and metric (optional).

Materials

.Contained in this module:

1. Activity Sheet #'s 1 to 11
2. Student Worksheet #'s 1, 1a, 3, 3a, 3b, 5, 5a, 7, 9, 11, 11a, and 11b.

.Teacher must provide:

1. String and weights (heavy washers will do) for pendulums, meter sticks, watches with second hand or stop watches. (Act. #2)
2. Meter sticks (Act. #3)
3. Strips of cardboard, tagboard (or adding machine tapes) 36 cm long, cardboard or tagboard for puzzle construction, meter sticks and metric rulers, 100 meter measuring tape, and scissors. (Act. #4)
4. Metric rulers, 1/2 gallon milk cartons, meter sticks, cardboard (40 cm long) for construction of cubic decimeter, cubic centimeter blocks, quart milk carton, liter measuring cup, and scissors. (Act. #5)
5. Balance scale with metric weights, various containers to hold water - tin cans, bottles, plastic bowls, etc. - white centimeter cubes, and 10 cm rods. (Act. #'s 6 and 7)
6. Celsius thermometer (not absolutely essential). (Act. #7)

Module Usage

This module may be used with an entire class. Some activities are best used by small groups of students.

Testing Procedures

Pretest

The pretest is designed to check entrance skills of students to determine if they need additional preparation before or during work on the module.

Students unsuccessful on the pretest may be:

1. Given pre-module materials,
2. Assigned to work on the module with better prepared students,
3. Given individual instructor help when difficulty is encountered within the module.

Posttest

The posttest is designed to determine if the student is able to succeed in accomplishing the objectives for the module.

Outline

I. Activity Sheet #1 - Introduction

A. Teaching suggestions:

1. The purpose of this activity is to discuss the need for history and advantages of the metric system.

2. This should be read and discussed by the students. The teacher could ask students to give examples of metric measurements that they have heard used. A 16 mm film projector, 35 mm slides are good examples. Some students may know of foreign or domestic cars with metric parts.

B. Materials:

1. Activity Sheet #1 and 1a
2. Student Worksheet #1 and 1a
3. Adding machine tape

C. Answer Key: Page 5

Solutions will vary.

II. Activity Sheet #2

A. Teaching suggestions:

1. The purpose of this activity is to illustrate a method of defining a standard measuring unit.

2. Students may do this experiment in pairs or threes. Be sure to emphasize that the measurement is to be made to the center (approximately) of the bob. Some discussion could take place regarding the displacement of the pendulum and it's effect on the period. If you pull it 5" to one side to start it swinging, do you get a different result from pulling it 8"? Where does it seem to make a difference? These questions should be answered by investigation.

B. Materials:

1. Activity Sheet #2 and 2a
2. String and weights (heavy washers will do) for pendulums, meter sticks, watches with second hands or stop watches.

III. Activity Sheet #3

A. Teaching suggestions:

1. This activity will help students learn names of basic metric units and prefixes for their subdivisions and multiples, and metric abbreviations.

2. The teacher should discuss the subdivision of the meter stick with the class and check their understanding of the prefixes and their meanings. Use the prefixes in other words - decimal, century, etc.

3. A game of "concentration" may be played with an overhead projector and a transparency of the following diagram.

	1	2	3	4
D	1 m	1 dm	1 cm	1 mm
C	1 Km	0.1 cm	1000 mm	0.1 m
B	10 mm	100 cm	10 cm	0.01 dm
A	10 dm	100 mm	0.001 m	1000 m

Easy for beginners. Other units can be used.

III. A. (Cont'd) The cells on the transparency may be covered with pieces of cardboard and the class divided into two teams. Then, taking turns, a member from each team tries to name the locations which contain equivalent measures, getting points for successes. For example, D-1 and C-3 scores a point. If the locations do not contain equivalent measures they are covered again. This game may be varied with different types of measurements as the students learn more about the metric system.

B. Materials:

1. Activity Sheet #3
2. Student Worksheet #'s 3, 3a and 3b
3. Meter sticks
4. Stock for playing cards.

C. Answer Key: Pages 10 and 11

1. Micro; milli; centi; deci; deka; hecto; kilo; and mega.

2. a) dekameter
   b) hectometer
   c) kilometer
   d) megameter
   e) centimeter
   f) decimeter
   g) milligram
   h) kiloliter
   i) kilogram

3. 1000 grams
   1 kilogram

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1. a) 10
   b) 10
   c) 100
   d) 10
   e) 1000
   f) kg
   g) 10
   h) 1000

2. a) 300 3
   b) 900 9000
   c) 3700 370
   d) 5 500

3. 8 cm; 89 mm; 607 mm; 242 cm; 47 dm; and 8 m

4. Solution is shown.

IV. Activity Sheet #4:

A. Teaching suggestions:

1. The activities provide opportunities for students to use metric measurements in constructing, measuring, and estimating. The teacher should circulate through the classroom to give assistance where needed.

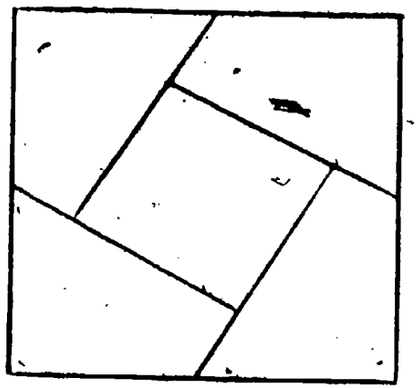
2. Games and puzzles may be used to encourage and motivate the students to learn metric measures. A good verbal game can start with the teacher saying: "I'm thinking of something in this room that is about 120 centimeters (or 1.2 meters) long." The student who guesses the object becomes the leader and repeats the process. Conflicting opinions may develop during this game and measuring instruments may have to be produced to settle the questions.

B. Materials:

1. Activity Sheet #4
2. Student Worksheet #4
3. Strips of cardboard, tagboard, (or adding machine tapes) 36 cm long
4. Cardboard or tagboard for puzzle construction
5. Meter sticks and metric rulers
6. 100 meter measuring tape
7. Scissors.

IV. C. Answer Key: Pages 12, 13, 14 and 15

1. All lengths from 1 through 36 can be measured directly with the "centimeter stick".

2. 

3.

Order	Estimate of Length	Actual Length	Error	Correct Order
		149 mm		C
		50 mm		B
		47 mm		G
		44 mm		D
		30 mm		H
		26 mm		E
		9 mm		A
		8 mm		F

4. Answers will vary

5.

Guessed Order	Est. of Perimeter	Actual Perimeter	Correct Order
		20 cm	D
		19 cm	C
		13 cm	B
		12 cm	A

V. Activity Sheet #5

A. Teaching suggestions:

1. The purpose of this activity is to provide experiences in defining and using metric measures of area.

2. Preliminary work with rubber band constructions or geoboards would be helpful for Student Worksheet #5, Problem 1.

B. Materials:

1. Activity Sheet #5
2. Student Worksheet #5 and 5a
3. Metric rulers
4. One-half gallon milk cartons
5. Meter sticks
6. Scissors

C. Answer Key:

(Activity Sheet #5) - Page 16

1. $100\ mm^2 = 1\ cm^2$
2. $100\ cm^2 = 1\ dm^2$
3. $100 \times 100 = 10{,}000$
4. $100\ dm^2 = 1\ m^2$
5. $1000 \times 1000 = 1{,}000{,}000$

(Student Worksheet #5) - Pages 17 and 18

1. A) $4\ cm^2$
   B) $9\ cm^2$
   C) $8\ cm^2$
   D) $9\ cm^2$
   E) $13\ cm^2$
2. a) An infinite number
   b) Any straight line which passes through the center point of the rectangle cuts it in half.
   c) $9\ cm^2$.
3. Answers will vary.
4. Answers will vary.

VI. Activity Sheet #6

A. Teaching suggestions:

1. The purpose of this activity is to provide experiences in defining and using metric measures of volume and capacity.

B. Materials:

1. Activity Sheet #6, and 6a
2. Metric rulers
3. Cardboard (40 cm x 30 cm) for construction of cubic decimeter
4. Cubic centimeter blocks
5. Liter measure
6. Quart carton
7. Scissors

C. Answer Key: Pages 19 and 20

1. a) 6 dm^2
   b) 600 cm^2.

2. a) 100 c) 1000
   b) 10 d) 1000

4. A liter is slightly larger than a quart. One quart is approximately .95 liters. One liter is approx. 1.06 quarts.

VII. Activity Sheet #7

A. Teaching suggestions:

1. The purpose of the activity is to provide experiences in using metric measures of mass.

2. Students could be divided into teams of three to work on measuring various items of the exercise and then switch equipment.

3. A good activity to promote skills in estimation and review all measurement learned up to this point is the following: Gather together 10-15 objects. Have a sheet prepared (by the teacher or a committee of students) which lists a measurement for each object - a length, mass, or capacity. Then have students, one at a time, list the name of the correct object next to its measurement. This can be done as a contest with a timer to see which student can complete the task in the shortest time. For example:

(Committee or teacher keeps master or solution sheet.)

Name or number of object	Measurement
_____	length of 30 cm
_____	width of 4 cm
_____	thickness of 3 mm
_____	length of 12 cm
_____	mass of 1 kg

B. Materials:

1. Activity Sheet #7
2. Student Worksheet #7
3. Balance scale with metric weights
4. Metric capacity measures, liters and cubic centimeters
5. Various containers to hold water - tin cans, bottles, plastic bowls, etc.
6. White and orange Cuisenaire rods.

C. Answer Key:

(Activity Sheet #7)

1. Answers will vary, but the mass of water should be about 1000 grams.
2. Answers will vary. 1 gram (if measured precisely under rigidly controlled conditions).

(Student Worksheet #7)

1. Answers will vary (students check each other.)
2. Slightly less than one gram, since wood is lighter than water.
3. Answers will vary.

III. Activity Sheet #8 (Optional)

A. Teaching suggestions:

1. Purpose is to provide experiences in using metric land measure

B. Materials:

1. Activity Sheet #8, and 8a
2. Metric-squared paper
3. Metric measuring tape (optional)

C. Answer Key: Page 23

1. Square centimeters (cm^2)
2. Square meters (m^2)
3. Square dekameters (dam^2)

IX. Activity Sheet #9

A. Teaching suggestions:

1. The purpose is to become acquainted with Celsius temperature scales.
2. Estimation of temperatures on the Celsius scale in class discussion should be helpful. What is a reasonable Celsius reading for human body temperature, refrigerator temperature, temperature at the North Pole, temperature of molten lava for a volcano?

B. Materials:

1. Activity Sheet #9
2. Student Worksheet #9
3. Celsius thermometer (not abs. essential)
4. Fahrenheit thermometer.

C. Answer Key:

(Activity Sheet #9) - Page 25

F	=	C
		-18°
		38°
		22°
		37°
		-177°
32°		
230°		
70°		
490°		

(Student Worksheet #9) - Page 27

1 a)

C	F
10°	50°
15°	60°
20°	70°
30°	90°
35°	100°

IX. C. (Continued)

(Student Worksheet #9) - Page 27

1 b) 20° - 35° or higher

c) 10° - 50°; 15° - 59°; 20° - 68°; 30° - 86°; 35° - 95°.

2. Subtract 30, then take one-half.

X. Activity Sheet #10

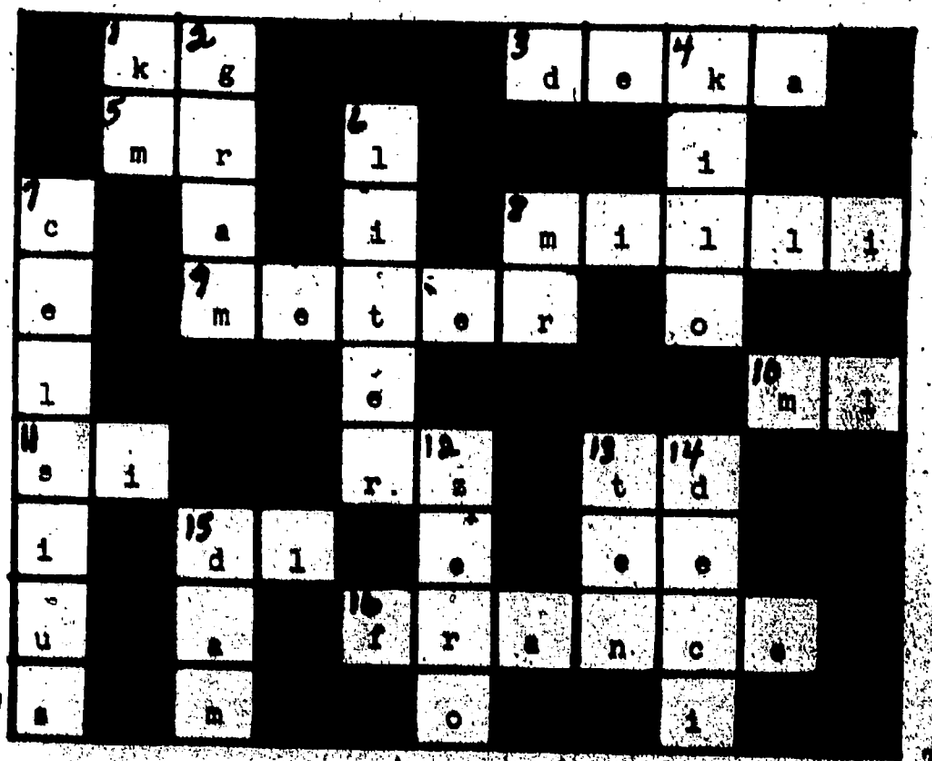
A. Teaching suggestions:

1. Activity #10 should be used as a review exercise, followed by a discussion of the entire unit.

B. Materials:

1. Activity Sheet #10

C. Answer Key: Page 28



XI. Activity Sheet #11

A. Teaching suggestions:

1. This activity will provide practice in comparing the most common units of the metric and English systems.
2. Emphasize the approximate nature of the conversions.
3. Give as many concrete experiences in "seeing" the units as possible.
4. Emphasize that conversions are increasingly unnecessary.

B. Materials:

1. Activity Sheet #11 and 11a
2. Student Worksheet #11, 11a, and 11b
3. Measuring units

C. Answer Key: Pages 32 and 33

1. a) 1 in. b) 1 m c) 1 mi. d) 1/2 in. e) 1 km f) 1 liter g) 1 kg h) 1 gal i) 1 kg
2. Multiply by 2 1/2. 150 cm.
3. Multiply by 1 1/2. 150 mi. 120 mph.
4. About the same in quarts. Divide by 4 for gallons. 40 qts. 10 gal.
5. Multiply by 2.2. 22 lb. $2.20 lb.
6. a) 80 b) 4 c) 91 d) 9 e) 25 f) 10 g) 15 h) 38 i) 9 j) 230 k) 93 l) 3 m) 1 n) 13 o) 4 p) 1 q) 4 r) 5 s) 11 t) 1

ANSWERS TO PRETEST

1. a) 1 inch b) 2 inches c) 4 inches

2. a) 1 inch b) 2 inches c) 3 inches

3. a) 3 feet
   b) 3 feet 4 inches
   c) 3 feet 6 inches
   d) 5 feet 4 inches

4. a) $1/10 = 0.1$
   b) $\frac{5}{10} = 0.5$
   c) $\frac{2}{100} = 0.02$
   d) $\frac{15}{1000} = 0.015$

5. a) $1000 = 10^3$
   b) $100 = 10^2$
   c) $\frac{1}{10} = 10^{-1}$
   d) $\frac{1}{1000} = 10^{-3}$
   e) $\frac{1}{100} = 10^{-2}$

6. $\frac{1}{10000}$, $\frac{1}{1000}$, $\frac{1}{100}$, $\frac{1}{10}$, 10, 100, 1000

7. a) 5 ft. 10 in.
   b) 8 ft. 8 in.

8. a) 8 inches
   b) 8 inches
   c) 12 inches
   d) 7 inches

9. 45° F

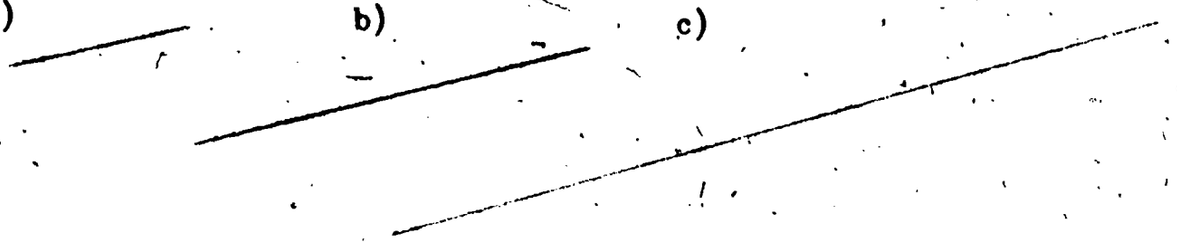
ANSWERS TO POSTTEST

1. Meter
2. Gram
3. Liter
4. Square meters or square dekameters
5. Cubic meters or cubic dekameters
6. a) 10^{-3}
   b) 10^{1}
   c) 10^{2}
   d) 10^{3}
   e) 10^{-1}
7. a) 600 cm = 6
   b) 4 km = 400
   c) 900 cm = 9000 mm
8. 50 cm.
9. 100
10. 1000
11. 1 gram
12. 100 cm^2
13. 0 degrees
14. 100 degrees
15. 70 degrees

PRETEST

1. Estimate the length of these line segments to the nearest inch.

a) b) c)



2. Measure the length of the following line segments to the nearest inch.

a) b) c)

3. a) How many feet is 36 inches?

Change the following to feet and inches.

b) 40 inches = _____ ft _____ inches

c) 3 1/2 feet = _____ ft _____ inches

d) 1 yard 2 ft 4 inches = _____ ft _____ inches.

4. Change the following common fractions to decimal fractions.

a) 1/10 = _____ c) 2/100 = _____

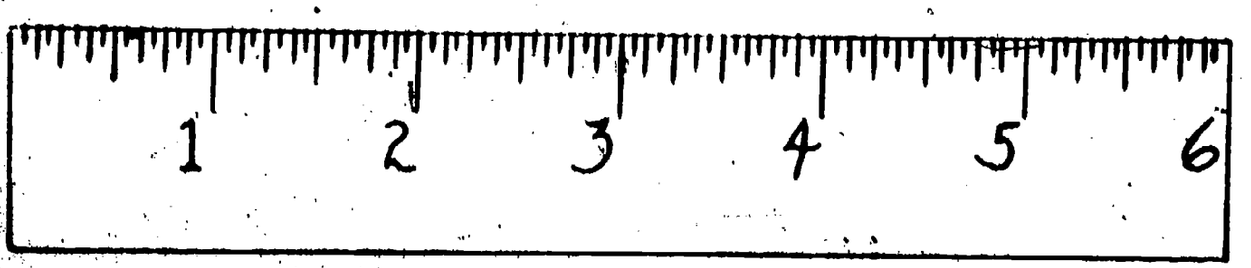
b) 5/10 = _____ d) 15/1000 = _____

5. Write the following as a power of ten.

a) 1000 = _____ d) $\frac{15}{1000}$ = _____

b) 100 = _____ e) $\frac{1}{100}$ = _____

c) $\frac{1}{10}$ = _____



PRETEST (Continued)

6. Order the following numerals from smallest to largest.

a) 1000 b) $\frac{1}{10}$ c) $\frac{1}{100}$ d) 10 e) $\frac{1}{10000}$ f) 100 g) $\frac{1}{1000}$

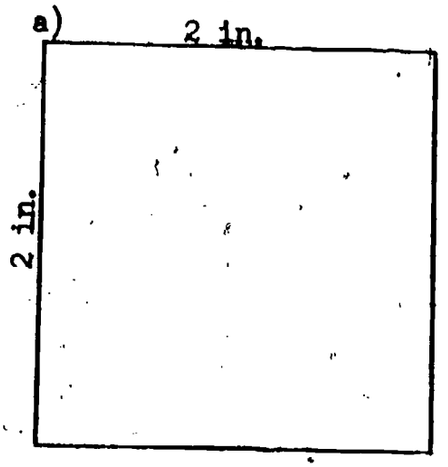
7. Add the following, using English units. Simplify if necessary.

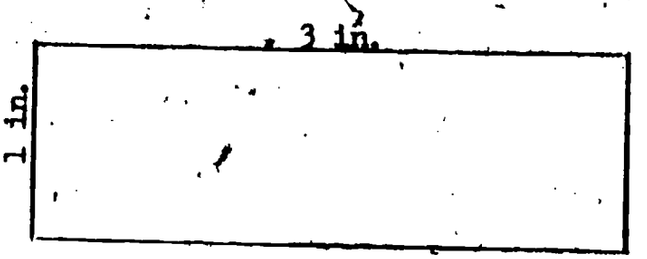
a) 3 ft. 2 in.
+ 2 ft. 8 in.

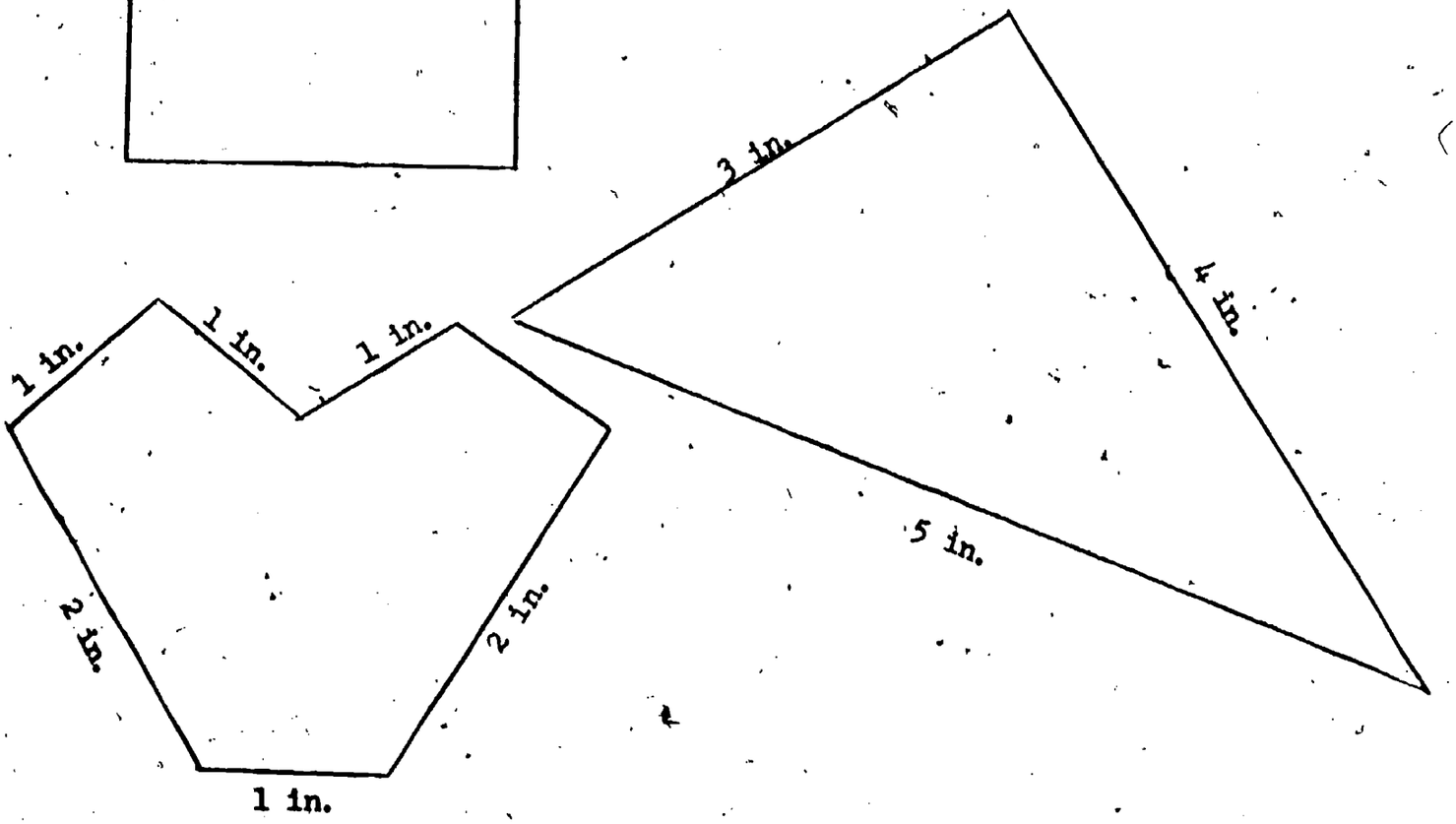
b) 5 ft. 10 in.
+ 2 ft. 10 in.

8. Find the perimeter (distance around the figure) of the following:

a)

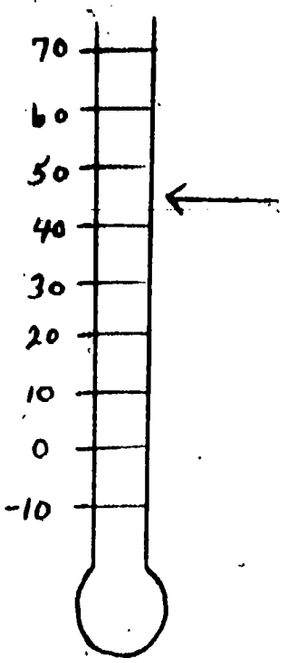






PRETEST (Continued)

9. What is the temperature in °F at the arrow (←)?



POSTTEST

1. What is the basic metric unit for length? _____

2. What is the basic metric unit for mass? _____

3. What is the basic metric unit for capacity (liquid mass)? _____

4. What unit might be used to measure the surface area of a classroom floor?

   _____

5. What unit might be used to measure the volume of your classroom?

   _____

6. Write each of the following prefixes as a power of ten:

   a) milli
   b) deka
   c) centi
   d) kilo
   e) deci

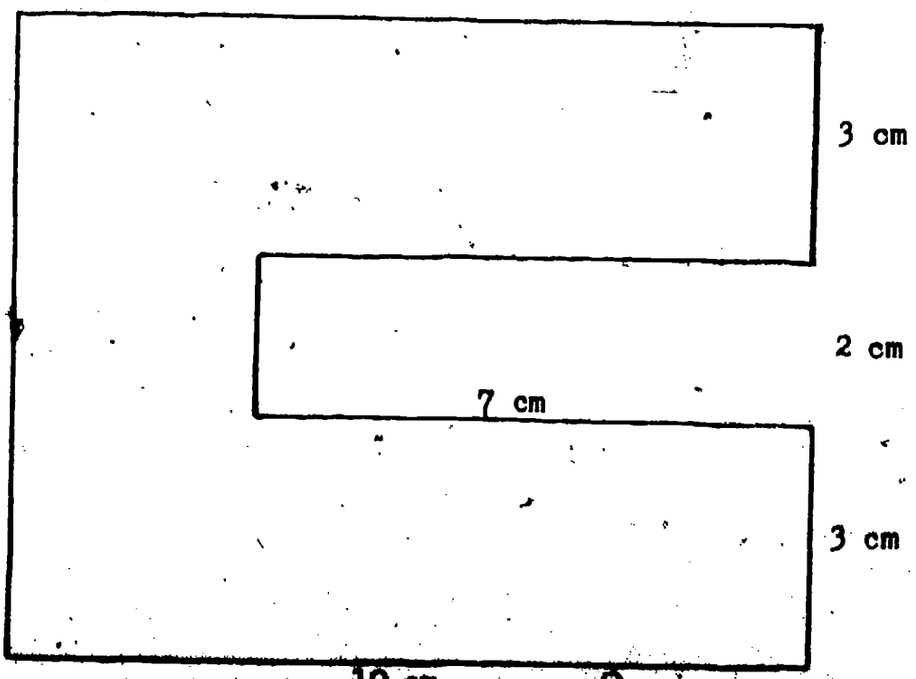
7. Fill in the blanks below.

   a) 60 dm = _____ cm = _____ m

   b) 4000 m = _____ km = _____ dam

   c) 9 m = _____ cm _____ mm

8. What is the perimeter (distance around) the following figure



POSTTEST (Continued)

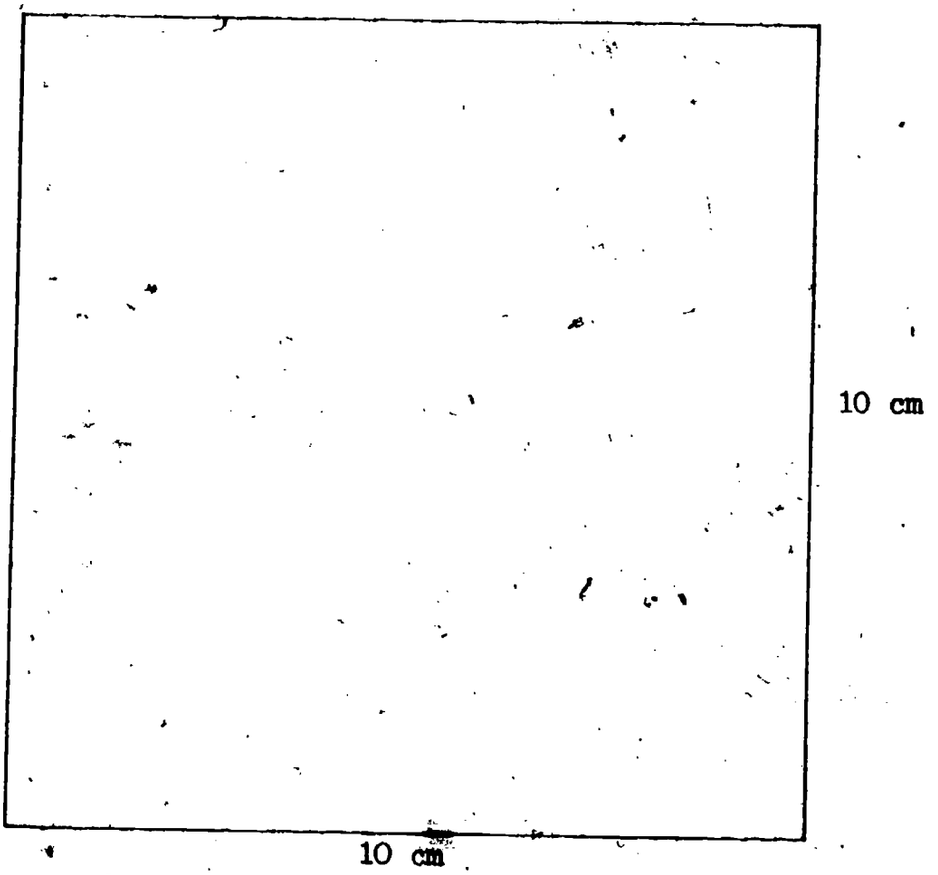
9. How many cubic centimeters would fit in a cubic decimeter box?

_____

10. How many cubic centimeters are contained in a liter? _____

11. What is the mass of one cubic centimeter of water at its greatest density? _____

12. What is the area of the following square? _____



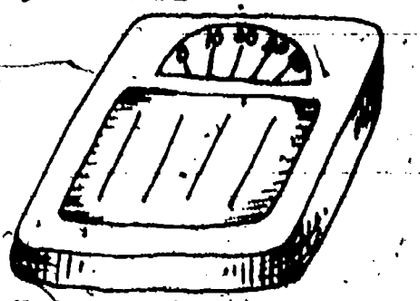
13. 32 degrees fahrenheit is equal to _____ on the celsius scale.

14. 212 degrees fahrenheit is equal to _____ on the celsius scale.

15. A celsius temperature of 20 degrees is approximately what fahrenheit temperature? _____

Activity Sheet #1

Introduction

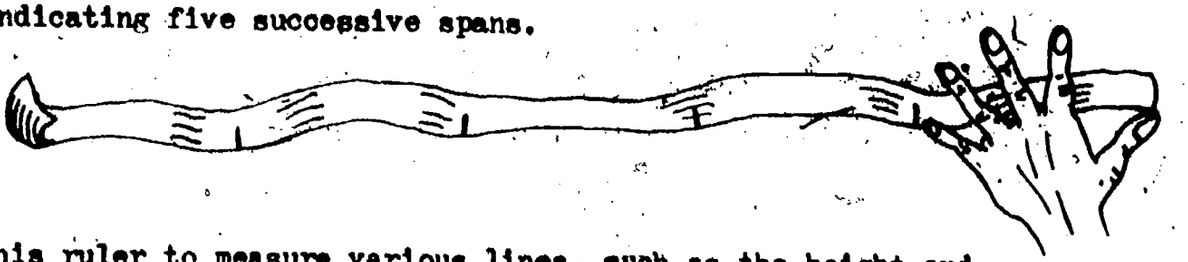


How tall are you?
How much do you weigh?
How large is the desk top?
How warm is the room?
How much milk did you drink for breakfast?

As you answered these questions you used measurements. You compared the objects in question with known units such as inches, feet, pounds, square inches, degrees, cups or pints. The units commonly used in the United States were formerly used in England and are known as the English system of measurement.

Long ago men measured the length of things by comparing them to parts of their bodies. For example, the span is the distance between the tips of the thumb and little finger when extended.

On the edge of a length of adding machine tape, make a measuring line (ruler) using your own span as the measuring unit. Make marks on the tape indicating five successive spans.



Use this ruler to measure various lines, such as the height and width of the door, length of this page, or the length of your pencil. Record the lengths. Are the measurements exact, or do you have parts of the lines left over? How could you make the measurements more exact (precise)? Compare your results with measurements made by other students. What disadvantages do you see in this kind of measurement?

Would the measurements be more satisfactory if everyone agreed to use the span unit and ruler of just one person? The one unit would be the standard unit for the class. If people agree, there can be standard units

for entire nations, such as our English standard system, or even for the world. Would this be desirable? What kind of a measuring system would you invent if you could make one for the world? What units? What names for the units? How would they be related to each other?

Different nations and groups of people have selected different measuring systems. If you like history and stories, often comical, you may enjoy finding out the origin of some of these units.

As science and trade developed, the old measuring systems proved to be more and more inconvenient and confusing, difficult to learn and to use. An efficient international measuring system was needed. In 1791 the Paris Academy of Science recommended a new decimal system of weights and measures.

In the new system, each unit of measure is the product of a basic unit and a power of ten. The Academy named the basic unit of length the meter from a Greek word meaning measure. The unit of mass (weight) is the gram and the unit of capacity (liquid measure) is the liter. Subdivisions and multiples of basic units are named by putting Latin and Greek prefixes before the basic unit. For example, deci means one-tenth so decimeter is one-tenth of a meter and decigram is one-tenth of a gram. They named the system the metric system.

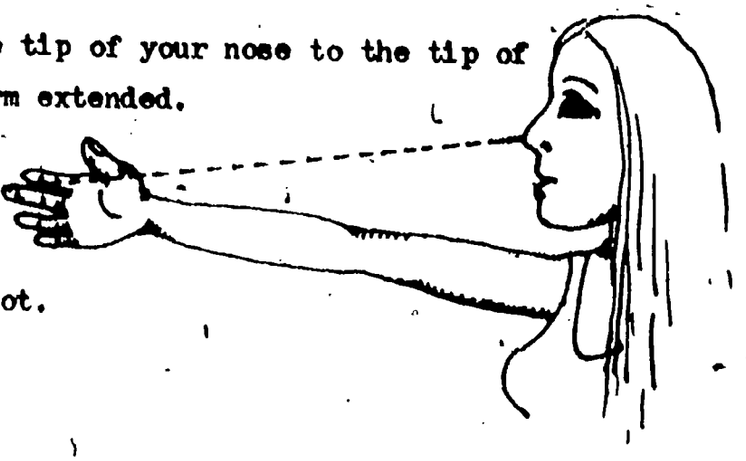
Although scientists and others engaged in international metric system, it took many years for countries to give up their own unscientific, inconvenient, but familiar national systems. Today the metric system is legal in every civilized country. The United States was the last industrialized nation in the world to officially adopt the system. It has been legal, though not official, since the nation was founded and is already widely used in science and business. It will probably completely replace the old English measurement system in a few years. Soon the entire world will be using the SI (System International), the metric system.


NON-METRIC

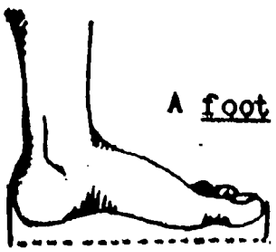
Body units, such as a hand or a foot, frequently have been used to make measurements. You may have seen some of them mentioned in stories and in history. You may even have used some of them. Over the years they have become standardized, but you can make approximations using your own body units.

A <u>cubit</u> is the distance from your elbow to the outstretched tip of your middle finger.

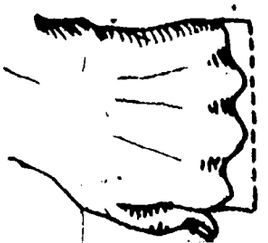
A <u>yard</u> is the distance from the tip of your nose to the tip of your middle finger with your arm extended.



A <u>foot</u> is the length of your foot.



A <u>hand</u> is the width of your hand across the knuckles.



An <u>inch</u> is the length of the joint at the end of your thumb.

Measure your own body units, using a standard ruler.

Body Unit	Standard Unit
Inch	
Hand	
Foot	
Cubit	
Yard	

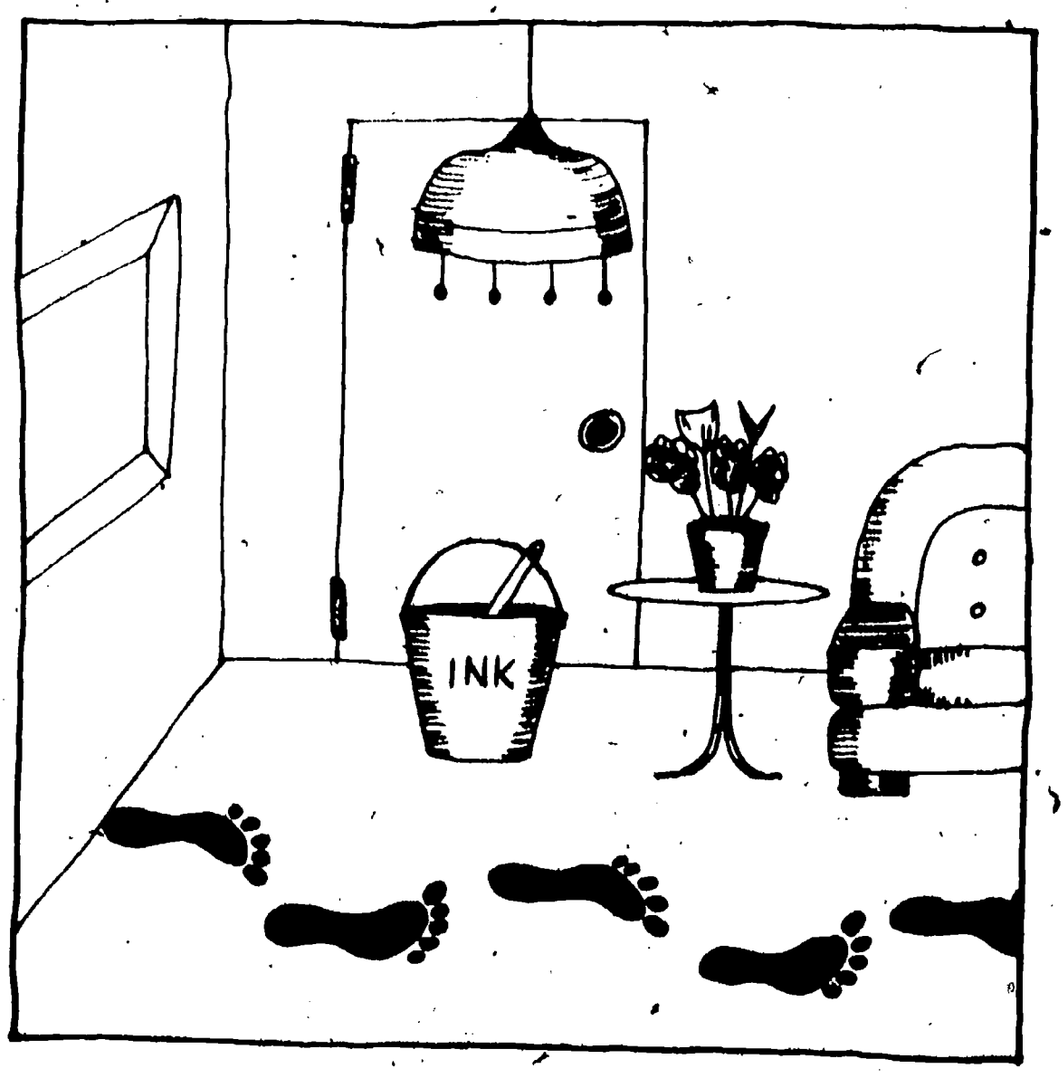
Are there any convenient relationships between your various body units? What are the relationships between the standard units?

Use one of your body units to make a ruler. Measure two or three things, then check with a standard ruler.

Optional

Another personal unit is a step (the length of your normal step from your back heel to your front heel). You have probably seen football referees step off penalties. What do you estimate the length of your step to be? Check it with a standard ruler.

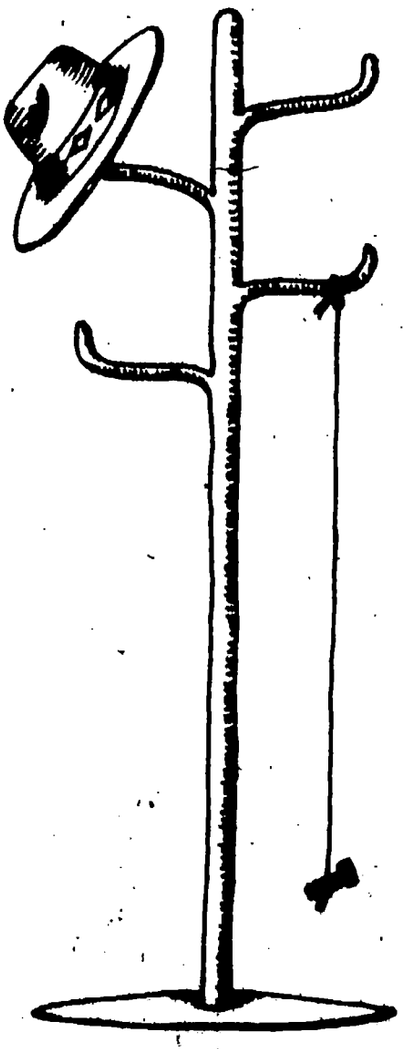
1. Step off and estimate the length of the room.
2. Check your estimate with a standard measure.
3. Try again on the length of the room or some other distances. Can you improve your estimates?



Thomas Jefferson, a Pendulum, and the Meter

The basic unit of length in the metric system is the meter. Through the years, many ways have been suggested to define the meter. One of the most interesting was advocated by Thomas Jefferson. In his method, the length of a single pendulum was to be used to define a meter.

A simple pendulum may be constructed from a length of string with a weight tied to one end. This weight is called the "bob". Construct a pendulum and fasten it to a support, as indicated below.



Activity Sheet #2a

Pull the bob a small distance to one side and let it swing back and forth. The period of a pendulum is the length of time it takes for the pendulum to swing from one side to the other and back again.

Jefferson's idea was to define the meter as the length of a single pendulum having a period of two seconds. In this experiment, we will see how close this is to a meter.

Start the pendulum swinging (remember, only small swings.)

a) When the motion is smooth, start timing with a watch and count ten complete periods (remember, one period is a swing from one side to the other and back again.)

b) If this takes less than 20 seconds, lengthen the pendulum; if it takes more than 20 seconds, shorten the pendulum.

c) When the time to complete ten periods is exactly 20 seconds, you have a length which we shall call a "pendumeter". Measure the length from the point where the pendulum is held to the center of the bob.

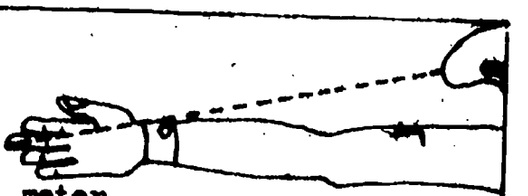
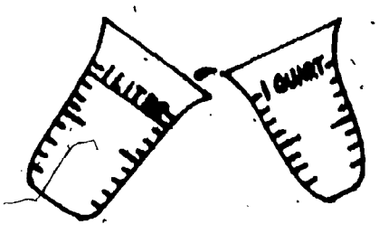
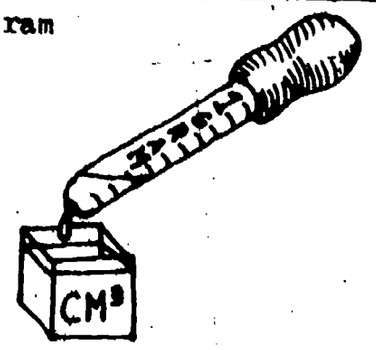
Compare your "pendumeter" with other groups. Compare the "pendumeter" with a meter stick. How close are the two lengths? An interesting thing about this equipment is that we have used time to determine distance. With the same apparatus, we could use distance to determine time by using a pendulum with a length of one meter. Then we could define one second as the length of time it takes the pendulum to complete a half period.

The "pendumeter" is not the official meter. The "pendumeter" is affected by the earth's rotation and the location at which the experiment is conducted. The official meter was originally defined as a unit equal to one ten-millionth of the distance between the equator and the North Pole. In 1960 a new standard, more readily determined, was defined. It bases the length of the meter on the wave length of the orange-red light from the gas Krypton.

How tall are you? There are various ways of answering this question. For example, you may say: 64 inches, or 5 feet 4 inches; 5 and 1/3 feet; or even 1 yard 2 feet 4 inches. Sometimes it is convenient, even necessary, to rename a measurement in other units. This is often difficult in the English system. It requires that you know a variety of names and relationships between units. Do you know the relationships between inches, feet and yards?

Renaming measurements in the metric system is simple because it is a decimal system, based on powers of ten. In a set of measurements, each unit is ten times the size of the next smaller unit. And all use the same base name, combined with a prefix that shows its decimal relationship to the basic unit.

The basic units for each kind of measurement are:

Length	Meter Area: meter x meter = sq. meter Volume: meter x meter x meter = cu. meter 
Capacity (liquid measure)	Liter 
Mass (amount of matter, weight)	Gram 

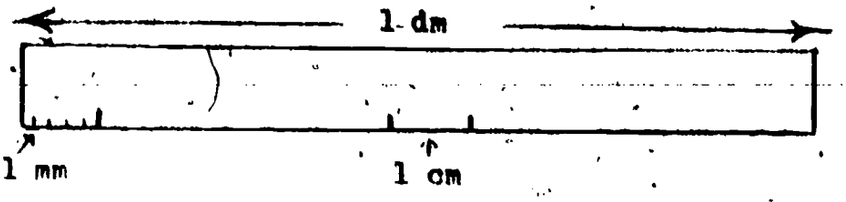
Latin prefixes are used for subdivisions of all types of metric measures.

deci - divided into tenths (0.1, 1/10, 10^{-1})

centi - divided into hundredths (0.01, 1/100, 10^{-2})

milli - divided into thousandths (0.001, 1/1000, 10^{-3})

Here is a picture (actual size) which shows the relationship of a decimeter, a centimeter, and a millimeter.



Greek prefixes are used for multiples of the basic units. They are:

deka - multiplied by 10

hecto - multiplied by 100 (10^2)

kilo - multiplied by 1000 (10^3)

You should learn these prefixes and their meanings. Note that it takes 10 of each unit to make the next larger unit, just as in our base ten numeration system. This relation between the metric system of measurement and the base ten system of numeration is one of the main advantages of the metric system. The same prefixes are used for units of length, area, volume, capacity, mass, and so on. For example, 1000 grams is a kilogram, 1000 meters is a kilometer.

Scientists have added two other prefixes for making measurements that are very small or very large.

> Micro means small and mega means great. But in the metric system micro means one-millionth (1/1,000,000) part of, and mega means one million times. There is one exception. Since micrometer was already a word meaning a measuring device, the word micron (abbreviated by using the Greek letter μ (mu)) is usually used to denote one-millionth of a meter. Also, the symbol for mega is (M).

1. Make a list of all the metric prefixes in order from smallest to largest.
2. Write the names for the units that are equal to
   a) ten meters
   b) one hundred meters
   c) one thousand meters
   d) one million meters
   e) one-hundredth of a meter
   f) one-tenth of a meter
   g) one-thousandth of a gram
   h) one thousand liters
   i) one thousand grams
3. In the metric system the units for length, volume, capacity, and mass are all related to each other. Under rigidly specified conditions of temperature and atmospheric pressure

   1 liter = 1000 cubic centimeters (cc) of water

   1 gram = the mass (weight) of 1 cubic centimeter of water.

   How much would a liter of water weigh? State your answer in two ways.

Here are some commonly used metric symbols. They combine the first letter of the prefix with the first letter of the basic unit, with several exceptions. What are the exceptions? Why? (See Student Worksheet #3.)

μm = micrometer	dam = dekameter
mm = millimeter	hm = hectometer
cm = centimeter	km = kilometer
dm = decimeter	Mm = megameter
m = meter	

1. Complete the following:
   a) _____ dm = 1 m
   b) _____ cm = 1 dm
   c) _____ cm = 1 m
   d) _____ mm = 1 cm
   e) _____ mm = 1 m
   f) 1000 g = 1 _____
   g) _____ cg = 1 dg
   h) _____ mg = 1 g
2. Fill in the blanks below:
   a) 30 dm = _____ cm = _____ m
   b) 9 m = _____ cm = _____ mm
   c) 37,000 cm = _____ dm = _____ m
   d) 5000 m = _____ km = _____ dam

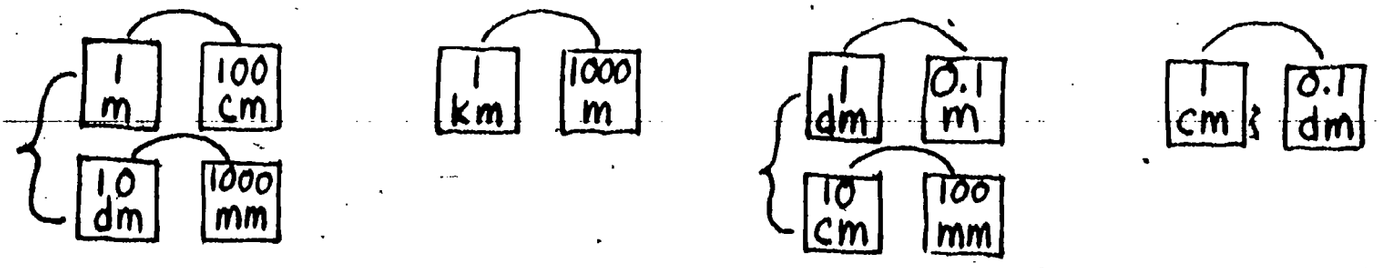
3. Put the following measurements in increasing order (smallest to largest):

8 cm; 47 dm; 242 cm; 89 mm; 8 m; 607 mm

4. Play Concentration

— Make a set of cards containing sets of equivalent pairs.

Some suggested pairs are:



Turn the cards face down.

The first player turns two cards face up.

If they are equivalents, he keeps them and turns two more.

If they are not equivalents, he turns them face down again.

The next player turns a card face up.

Before turning the second card, he tries to remember the previously turned cards, so he may match his face-up card. He then turns a second card.

If his turned pair are equivalents, he keeps them and turns two more.

A player continues turning pairs as long as they are equivalents, when the pair is not equivalent, the cards are turned face down, and the next player takes his turn.

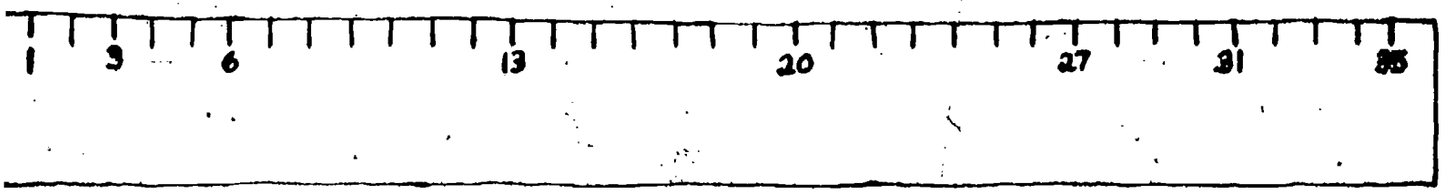
The player who takes the most cards wins.

Increasing the number of cards makes the game harder. Eight cards is easy.

Metric Measurement Projects and Exercises

1. A Strange Measuring Instrument

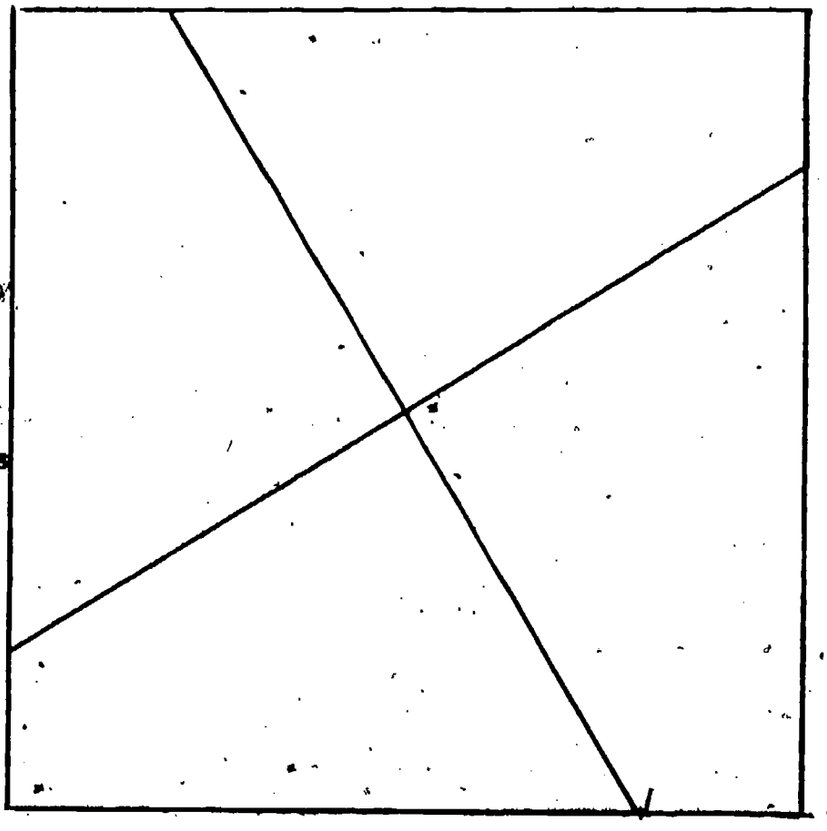
Make a cardboard "centimeter stick" (36 centimeters long) and mark only the points shown at distances 1, 3, 6, 13, 20, 27, 31 and 35 centimeters from the left-hand end.



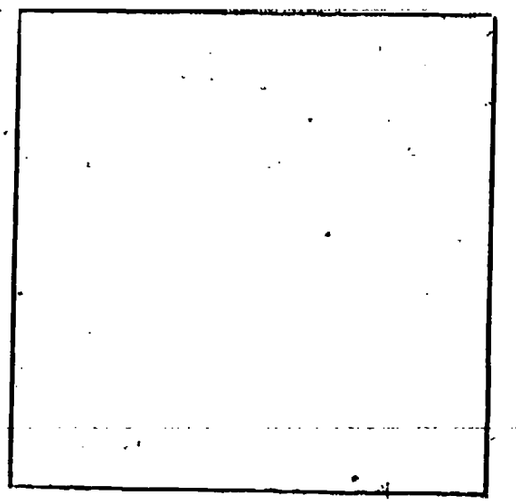
A point 11 centimeters from the left-hand end is not marked; however, the stick can be used to measure directly a length of 11 centimeters by using the markings for 20 and 31 centimeters. Between what two markings on the stick is there a distance of 2 cm? Using only the markings on the stick, can you measure directly a length of 8 cm? How many different lengths can be measured directly on the stick, using only the given marks? Show how each may be measured.

2. A Puzzle

Cut a ten centimeter (1 decimeter) square. Working in one direction around the ten centimeter square, mark one point on each side two centimeters from the corner. Join the points on opposite sides. (See illustration.) Cut along the lines making four pieces. Mix up the pieces and see if you can put it back together again. Sides which touch must have equal measurements.

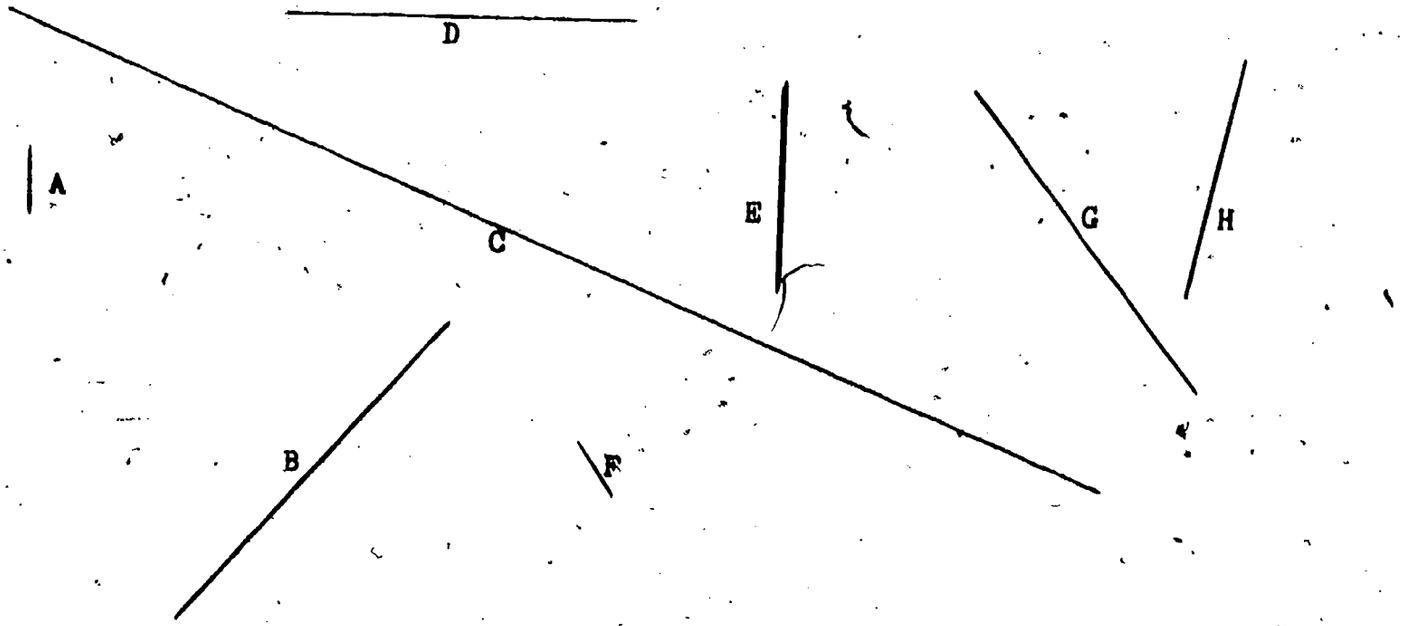


2a. Cut a six-centimeter square from cardboard. Combine this square with the four pieces of the 10 cm square you cut in #2 to make a larger square.



3. Estimating Metric Lengths

Just by looking, order the line segments with respect to decreasing length. Fill in the table.



	Order	Estimate of Length	Actual Length	Error	Correct Order
Longest		mm	mm	mm	
		mm	mm		
		mm			
Shortest					

Now write each length in cm.

4. Estimate first and then use the meter stick to measure each of the following. See if you can improve your estimating ability as you work through these problems.

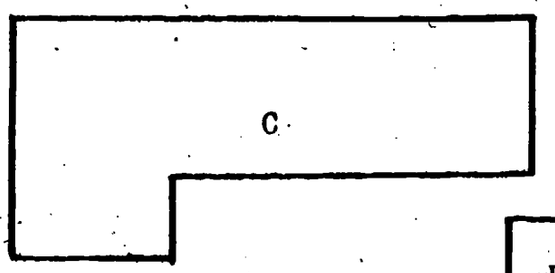
	Estimate	Actual Measure
a) Length of your pen or pencil		
b) Width of this paper		
c) Length of your little finger		
d) Height of the letter "E"		
e) Diameter of a piece of chalk		
f) Length of a friend's arm		
g) Distance you can jump from a position with both feet together		
*h) Distance you can run in approximately four seconds.		

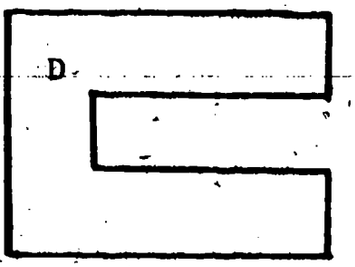
Pick two other items to estimate and measure.

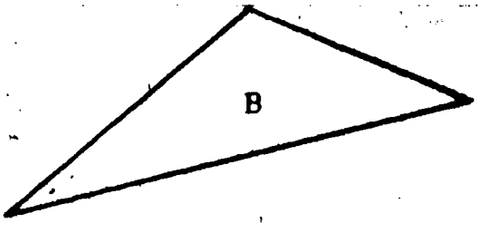
i)		
j)		

*Optional exercise for use outside, in good weather.

5. List the following figures in order of decreasing perimeter. (Perimeter is the distance around a figure.) Check yourself by measuring the perimeter of each.







	Guessed Order	Estimate of Perimeter	Actual Perimeter	Correct Order
Largest perimeter				
Smallest Perimeter				

Area and Volume Measurements

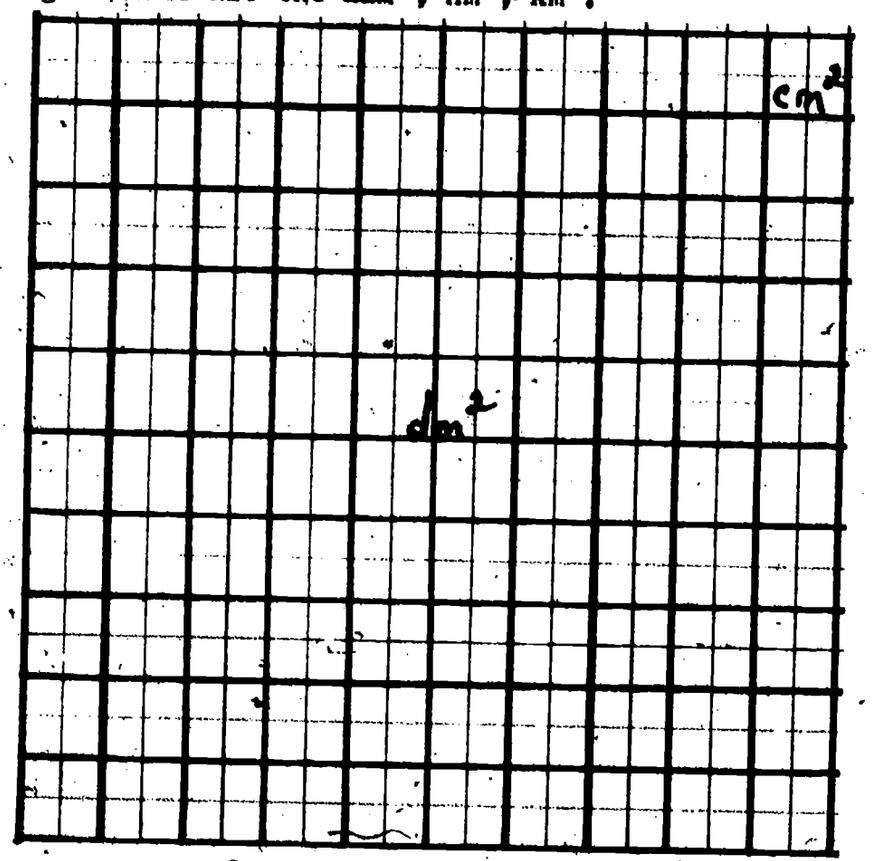
To measure length we need a line. The basic unit of linear measure is a line 1 meter long.

To measure a surface, for instance the floor of the room or this page, we need a surface (or area) unit.

The basic unit of area is a square meter, a square whose sides are lines one meter long. Subdivisions of the square meter (m^2) are the

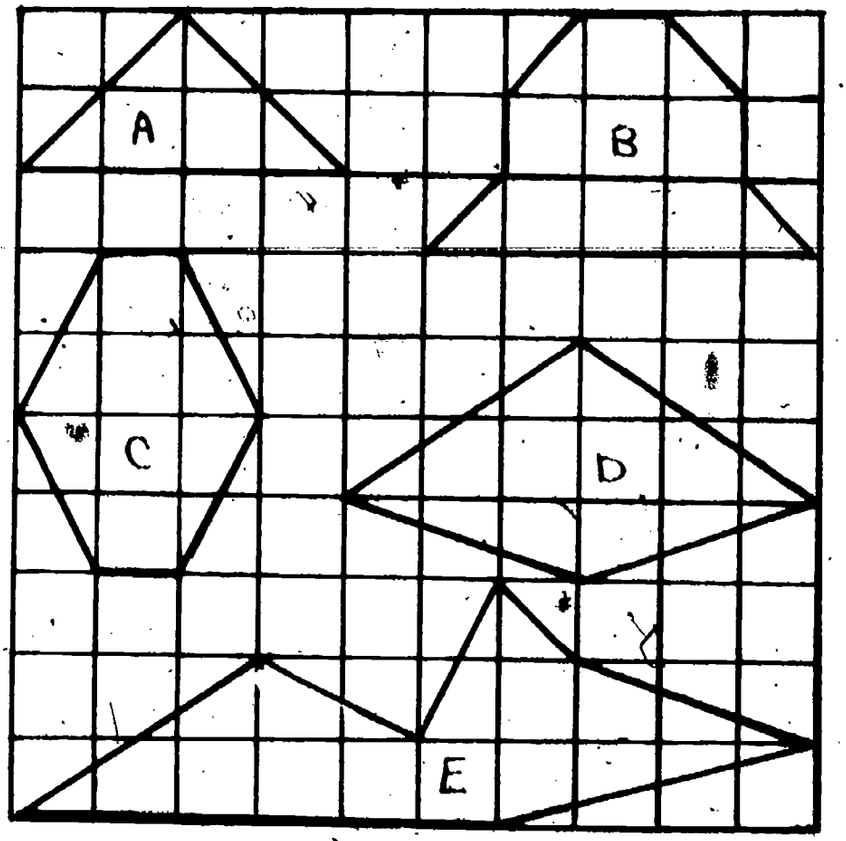
square decimeter dm^2
square centimeter cm^2
square millimeter mm^2.

Larger units are the dam^2, hm^2, km^2.



1. How many mm^2 = 1 cm^2?
2. How many cm^2 = 1 dm^2?
3. How many mm^2 = 1 dm^2?
4. How many dm^2 = 1 m?
5. How many m^2 = 1 km^2?

1. The figure below pictures a square decimeter divided into 100 square centimeters. Determine the area (in square centimeters) of the figures marked A-E.



A. _____ D. _____

B. _____ E. _____

C. _____

2. On a cm square paper, draw a rectangle 6 cm by 3 cm and draw a straight line which cuts it in half.

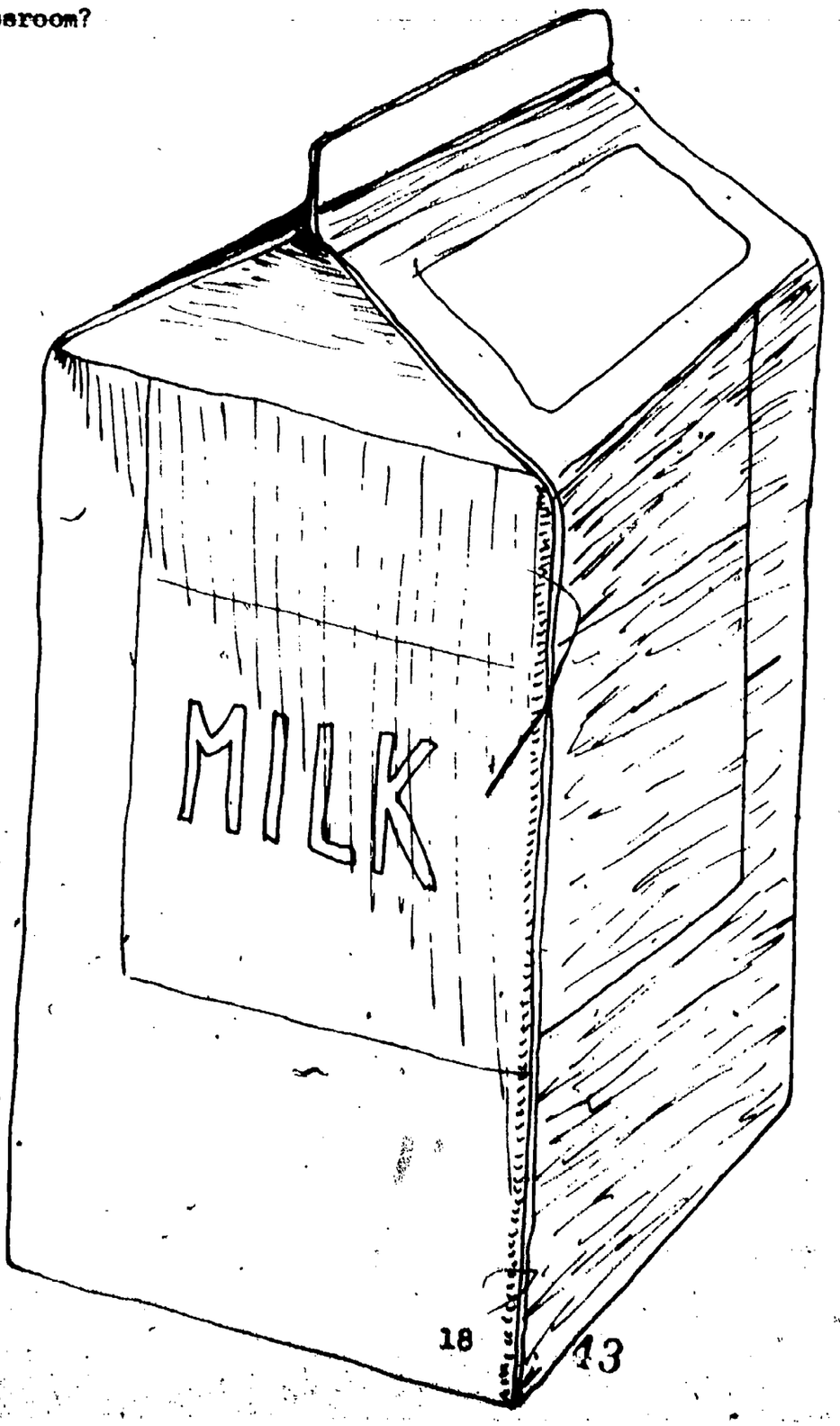
a) How many straight lines can be drawn which would cut the rectangle in half?

b) How can you be sure that a straight line cuts the rectangle in half?

c) What is the area of each part of the rectangle when it has been cut in half?

3. Approximate the number of square decimeters of cardboard it takes to make a one-half gallon milk carton. Cut the carton open, spread flat, measure and calculate the number of square decimeters in the carton. Or trace the parts of the carton on cm^2 paper.

4. Estimate the area (in square meters) of the classroom you are in. Measure and see how close your estimate was. If your teacher approves, mark off the square meters in chalk or string on the floor. If carpet costs $12.75 per square meter, what would be the cost of carpet for your classroom?

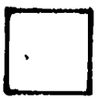


Volume and Capacity

To measure the length of a line we need a unit that models the line, a linear unit such as a centimeter or a meter.

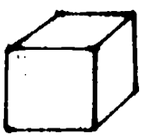
CENTIMETER

To measure a surface we need a unit that covers a surface, such as a square centimeter SQUARE CENTIMETER



To measure a three dimensional object, such as a box or a room, we need a three dimensional unit; for example, a cube like a sugar cube or a uniform box.

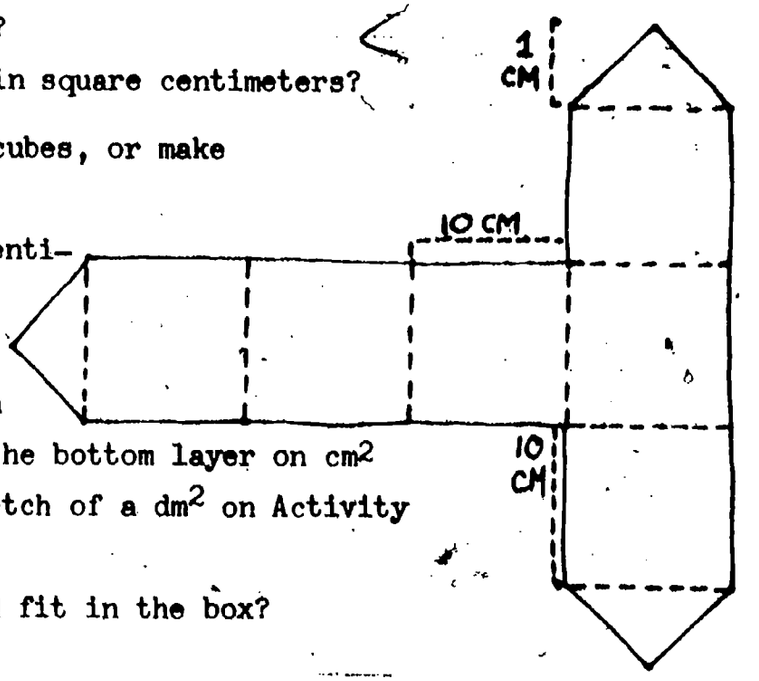
CM^3



1. Cut from cardboard, tagboard or centimer square graph paper, a pattern for constructing a cubic decimeter. (See illustration.) Fold and fasten the edges with tape leaving the top hinged open.

   a) What is the surface area (area of the pattern) of this cube in square decimeters?

   b) What is the surface area in square centimeters?



2. Obtain some white centimeter cubes, or make some cm^3 cubes.

   a) Estimate how many cubic centimeters it would take to cover the bottom of the cubic decimeter box with a layer 1 cm deep. Sketch the bottom layer on cm^2 paper, or refer to the sketch of a dm^2 on Activity Sheet #5, Example 1.

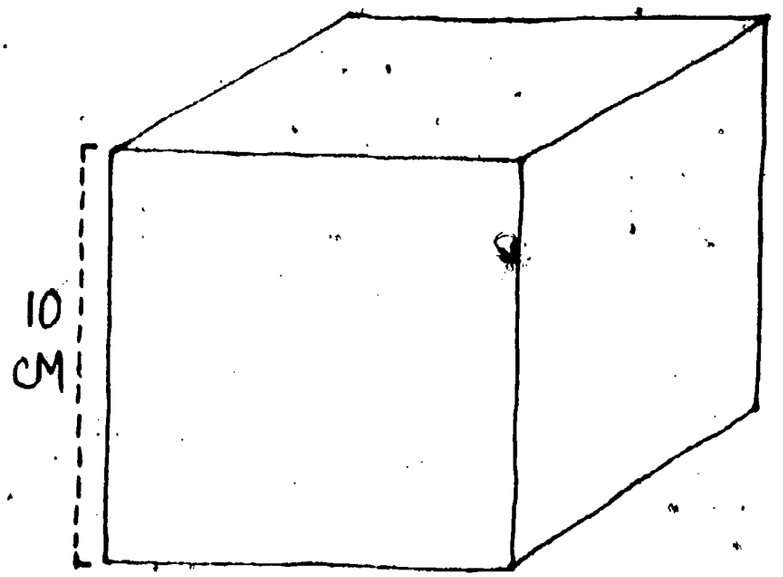
   b) How many such layers would fit in the box?

2. c) How many cubic centimeters would fit in the cubic decimeter box?

d) _____ cm^3 = 1 dm^3.

3. The basic unit of capacity (liquid measure) in the metric system is the liter. A liter is a unit of measure similar to a quart. In metric countries people buy soft drinks, milk, gasoline, etc. measured in liters. Look at your cardboard cubic decimeter box. If it would hold water, it would hold one liter.

In other words, a liter is a unit of volume equal to a cubic decimeter or 1000 cubic centimeters (cc).



This relationship between units is a property of the metric system which is not common to the English system. There is no direct relationship between cubic inches and quarts as there is between a cubic decimeter and a liter.

4. Fill a metric measure of 1 liter with water and pour it into a quart container (a milk carton will do). Did it fill the quart container? Was there any left over? Fill the quart container and pour it into the liter measure. Did it fill the liter measure? Was there any left over? Make your own rough comparison between a liter and a quart.

Investigating Measures of Mass

Obtain a liter (1000 cm^3) container. Find its mass on a balance. Record its mass. Carefully fill the container to the 1000 cm^3.

Find the total mass of the container and water. Record its mass. From the total mass, subtract the mass of the container to find the mass of 1000 cm^3 of water.

1. What is the mass of the water?
2. What is the mass of 1 cm^3 of water?

There is a direct relationship between units of volume (or capacity) and units of mass in the metric system. The unit of mass, the gram, is defined as the mass of one cubic centimeter of water (at its greatest density.)

So, the mass of 1000 cm^3 or 1 liter of water is ___ g or ___ kg.

You now have some concrete experience with a kg mass. If you could construct a cubic centimeter and fill it with water, you would have an idea of a gram weight. It takes only a small number of drops of water to fill a cubic centimeter.

Obtain a container graduated (marked) to measure cubic centimeters. Use an eyedropper to determine the number of drops in 1 cubic centimeter. How many? Compare your results with others.

Mass of one cm^3 of water = 1 gram

Examine the various masses in the set of metric weights to get the "feel" of them.

Investigating Measures of Mass

1. Obtain at least six containers that will hold water - tin cans, bottles, plastic dishes, soap or ice cream containers, empty pill containers, buckets, etc. Record their masses. Estimate the number of liters or milliliters in each container and the number of grams of mass of each. Now measure them with your metric measuring instruments. See if you can improve your estimates with practice. List your results in the table below.

Item	Estimated Capacity	Estimated Mass	Measured Capacity	Measured Mass
1.				
2.				
3.				
4.				
5.				
6.				

2. Would a cubic centimeter of wood (white centimeter cube) have a mass more or less than one gram? (Remember the definition of a gram.) Find the mass of one and find out if you are right.

3. Find the mass (in grams) of each of the following:

a) a 10 cm rod

b) a book

c) a pair of glasses

d) a watch

e, f, g) three other things you choose.

Metric Land Area Measurement

(Optional)

1. To find the area of this page, which metric unit would you use? Why?

2. To find the area of the room, which unit would you use? Why?

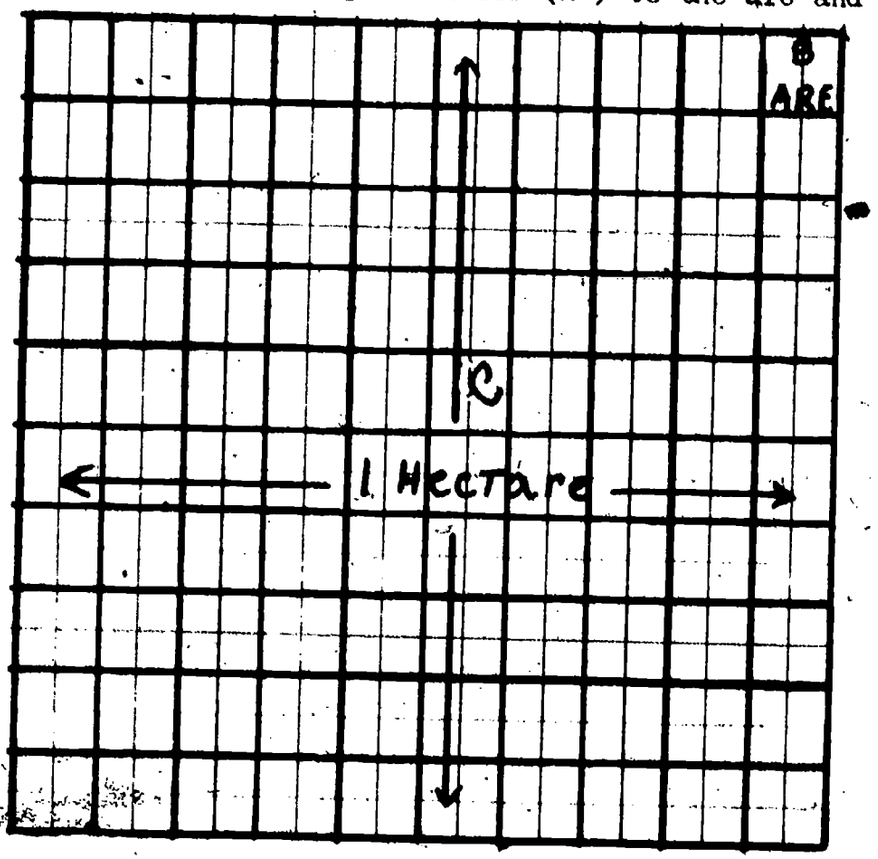
3. To find the area of the block of land the school is on, which metric unit would be convenient?

For convenience in measuring land areas, the metric system has two other commonly used units.

The <u>are</u> = 1 square dekameter = 100 square meters

The <u>hectare</u> = 10 square dekameters = 100 ares.

The scale diagram below (with 1 mm representing 1 m) shows the relationship of the square meter (m^2) to the are and hectare.



A = 1 square meter (m^2)

B = 1 square dekameter (dam^2) = 1 are

C = 1 hectare (ha) = 100 are = 10,000 m^2.

1. 1 hm = ____ dam
2. 1 dam = ___ m
3. Are = 1 dk^2 = ___ m^2

Outdoors

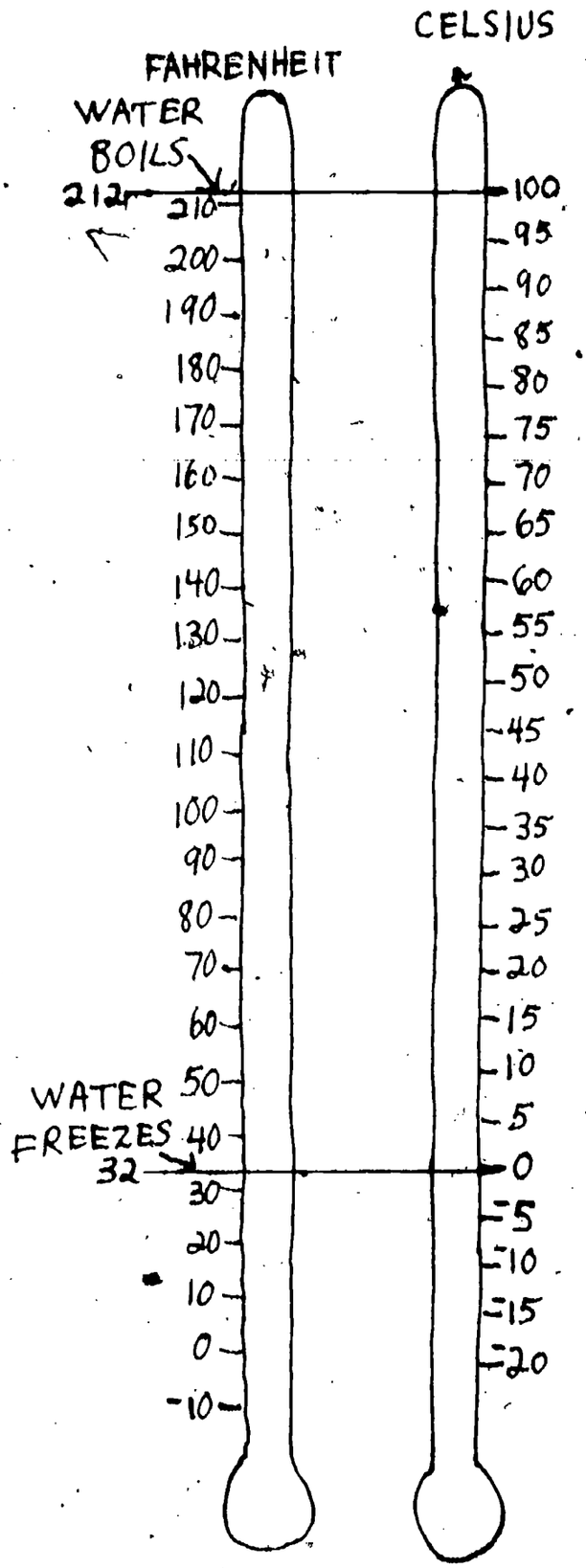
1. On the school playground, measure off an are = dam^2 = (10 m x 10 m).
2. Can you think of a familiar room or area about equivalent to an are?
3. If possible, measure off a hectare (100 m x 100 m).
4. Approximately how would a hectare compare with a football field?
   a) Make a scale drawing of a hectare (100 m x 100 m) with a football field outlined on it. (Use meters instead of yards for dimensions of the football field. Meters are only a little longer than a yard. Compare a yardstick and a meter stick.)

Metric Temperature Measurement

Just as other metric measures are based on multiples of ten, the metric temperature (Celsius) scale divides the interval between the freezing point and boiling point of water into 100 degrees. (The chart on the next page shows the relationship between the Fahrenheit and Celsius temperature scales.) You may be able to obtain both Celsius and Fahrenheit thermometers and make your own comparisons.

You can read equivalent temperatures from the illustrated scales by laying a straight edge straight across both at the desired temperature. Use this method to find the following equivalents:

Fahrenheit	Celsius
0°	___
100°	___
72°	___
98.6°	___
350°	___
___	0°
___	100°
___	20°
___	230°



COMPARE THE FAHRENHEIT AND CELSIUS THERMOMETERS

Many weather forecasts now give temperatures in both Fahrenheit and Celsius scales. A formula for converting Celsius readings to Fahrenheit can be formed. When the temperature of water changes from the freezing point to the boiling point, the Fahrenheit thermometer rises ____ degrees (from 32° to 212°). The Celsius thermometer rises ___ degrees (from ___° to ___°). Thus, a Fahrenheit thermometer must rise $\frac{180}{100}$ (or $\frac{9}{5}$) times as much as a Celsius thermometer to indicate the same temperature change.

$$F = 9/5\ C + 32$$

That is, multiply the Celsius reading by 9/5 and add 32° to get the corresponding Fahrenheit reading. You can make a rough approximation of this by saying $9/5 \doteq 2$ and $32 \doteq 30$. Then a rule of thumb for daily weather temperature reading is to "double and add 30". Thus, if the weather forecaster in a metric country forecasts a high of 25°, you can double and add 30 to get a close estimate of the Fahrenheit temperature (about 80°).

1. a) Use the "rule of thumb" to estimate the Fahrenheit temperature reading which correspond with each of the following Celsius readings.

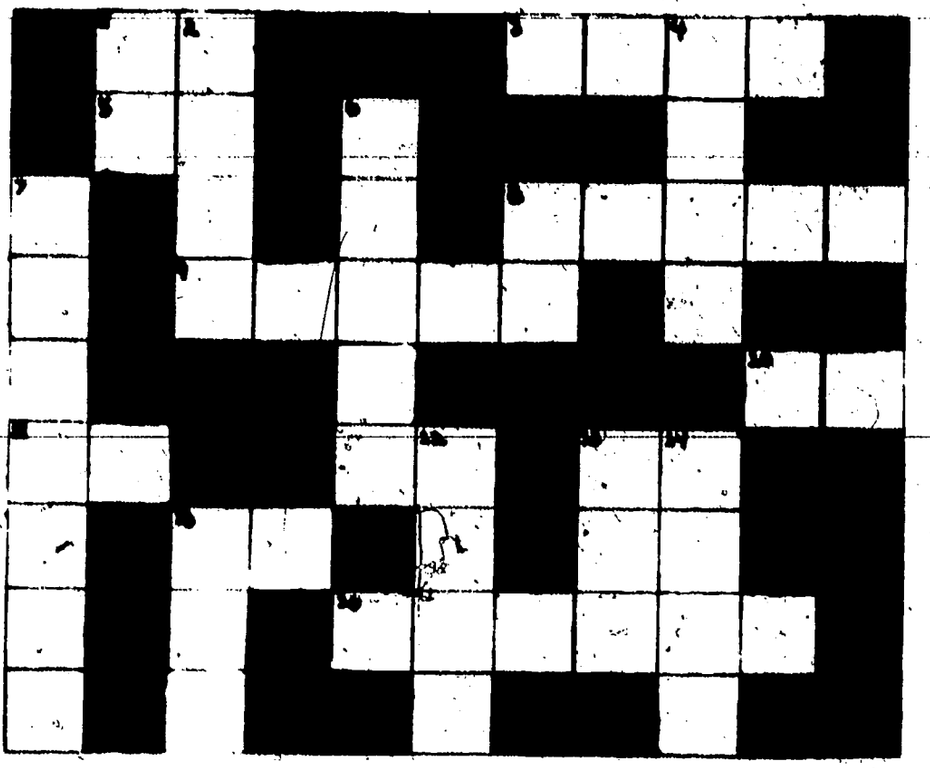
Celsius	Fahrenheit Estimate
10°	
15°	
20°	
30°	
35°	

Check by putting a straight edge across the scales on Activity Sheet #9.

b) In what temperature range (Celsius) would it be comfortable to go swimming?

c) (Optional) Find the exact temperature conversion for the Celsius readings in part a) by using the exact formula.

2. Can you figure out a rule of thumb for changing Celsius to Fahrenheit?



ACROSS

1. Abbreviation for kilogram
3. Prefix meaning "multiplied by 10"
5. Man's title
8. Prefix meaning "one-thousandth"
9. Basic unit of length
10. Abbreviation for milliliter
11. The initials of the official name of the type of metric we use
15. Abbreviation for deciliter
16. Country which originated the metric system

DOWN

1. Abbreviation for kilometer
2. Unit of mass
4. Prefix meaning "multiplied by 1000"
6. Basic unit of capacity
7. Name of temperature scale
12. Freezing temperature of water in SI units
13. Number of centimeters in a decimeter.
14. Prefix meaning "one-tenth"
15. Abbreviation for dekameter

Conversions

(Changing from one measuring unit to another)

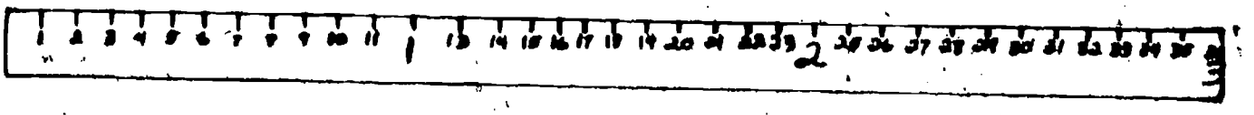
Optional

About the only use made of conversions is by Americans who are not yet familiar with the metric system. They may want to make comparisons of metric measurements with the system they already know. For this purpose, approximations are suitable.

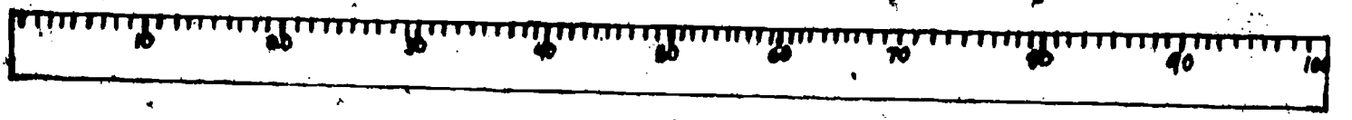
Place a meter stick and a yard stick together so that both zero points are touching. Compare the two measuring units - metric and yard. Which is longer? How much longer? Which statements most accurately describe their relationship?

1 yard	0.5 meters	1 meter	0.5 yards
1 yard	0.75 meters	1 meter	0.75 yards
1 yard	0.9 meters	1 meter	0.9 yards
1 yard	1.5 meters	1 meter	1.5 yards
1 yard	1.1 meters	1 meter	1.1 yards

YARDSTICK



METER STICK



Place a meter stick and a yard stick together so that both zero points are touching. Compare the two units -- centimeter and inch. Which is longer? How much longer? Which statements most accurately describe their relationsip?

1 cm	0.25 in	1 in	0.25 cm
1 cm	0.5 in	1 in	0.5 cm
1 cm	2 in	1 in	2 cm
1 cm	2.25 in	1 in	2.25 cm
1 cm	2.5 in	1 in	2.5 cm

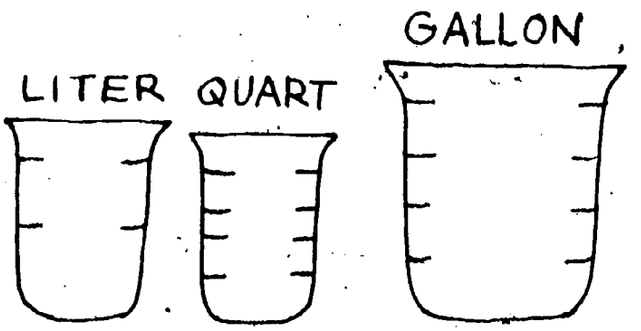
Approximate Conversions

Length

1 yd	0.9 m	1 m	1.1 yd
1 in	2.5 cm	1 cm	0.4 in (a little less than 1/2 in)
1 mi	1.6 km (a little more than	1 km	0.6 mi (a little more than 1/2 mi)

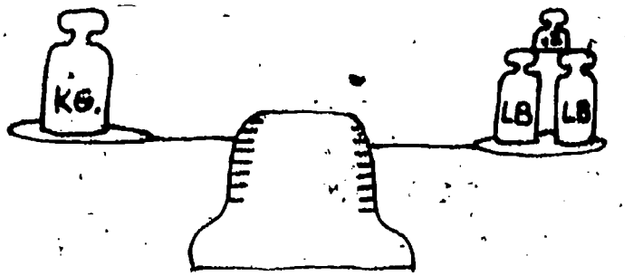
Capacity (liquid measure)

1 qt	0.95 liters	1 liter	1.05 qt (very little more than qt)



Mass (weight)

1 pound (lb)	0.5 kg	1 kg	2.2 lb



Since the meter is universally used, the United States has defined the yard as exactly equal to 0.9144 meters. 0.9144 can be exactly divided by 36 so

1/36 of a yard = 0.0254 meters
1 inch = 0.0254 meters
1 foot = 0.3048 meters.

All other equivalents in the two systems are approximations.

Although the exact relationships of the yard and meter and the inch and centimeter are known, there is ordinarily little use for them. The metric system is used almost exclusively in precise measuring activities and there is no need for conversion.

1. Which is larger?

a) 1 in or 1 cm	d) 1 cm or 1/2 in	g) 1 kg or 1 lb
b) 1 yd or 1 m	e) 1 km or 1/2 mi	h) 1 liter or 1 gal
c) 1 mi or 1 km	f) 1 liter or 1 qt	i) 1/2 lb or 1 kg

2. If you know your height in inches, how would you find it in cm?

   60 in = ___ cm

3. If you know a distance in km, how would you find it in miles?

   50 km = ___ mi

   80 km per hour = ___ miles per hour

4. If you know an amount in liters, how would you find it in quarts? gallons?

   40 liters = ___ quarts; = ___ gallons

5. If you know a weight in kilograms (kilos), how would you find it in pounds?

   10 kg = ___ pounds

   $1 a kg = $___ per pound

If you are traveling in another country, you will probably see signs like the ones below. Give their approximate equivalents in the English system. (Use the table on the Activity Sheet as needed.)

6. Complete the following conversions. Approximate to the nearest whole number. (Remember, ≐ means "approximately equals).

a) 50 mi ≐ ___ km
b) 2 1/2 mi ≐ ___ km
c) 100 yd ≐ ___ m
d) 10 yd ≐ ___ m
e) 10 in ≐ ___ cm
f) 4 in ≐ ___ cm
g) 16 qt. ≐ ___ l
h) 10 gal ≐ ___ l
i) 20 lb ≐ ___ kg
j) 1/2 lb ≐ ___ g
k) 150 km ≐ ___ mi
l) 5 km ≐ ___ mi
m) 1500 m ≐ ___ mi
n) 4 m ≐ ___ ft
o) 10 cm ≐ ___ in
p) 2.5 cm ≐ ___ in
q) 4 l ≐ ___ qt
r) 20 l ≐ ___ gal
s) 5 kg ≐ ___ lb
t) 0.5 kg ≐ ___ lb